

The Influence of Convection on the Anodic Oxide Formation of Aluminum Studied and Modeled in a Wall-Jet Electrode Reactor

I.De Graeve, H.Terryn,¹G.Nelissen, ²P.Vankeirsbilck
Free University of Brussels,
Dept. of Metallurgy, Electrochemistry and Materials
Science, ¹Dept.of Electrotechnical Engineering,
Pleinlaan 2, 1050 Brussels, Belgium.
²ElSyCa NV, Kranenberg 6, 1731 Zellik, Belgium.
idgraeve@vub.ac.be, hterryn@vub.ac.be

During anodizing of aluminum considerable heat is produced mainly by Joule heating of the electrode. Since the oxide formation mechanism is dependent on the thermal conditions, a temperature increase can influence the anodic film characteristics. Electrolyte agitation during the process plays an important role in distributing and removing this heat. In a wall-jet electrode reactor, the anodizing process is studied under controlled convection. Figure 1 is a schematic diagram of the wall-jet electrode reactor cell and hydrodynamic flow pattern [1]. The sample holder is equipped with five thermocouples to continuously monitor the local electrode temperature.

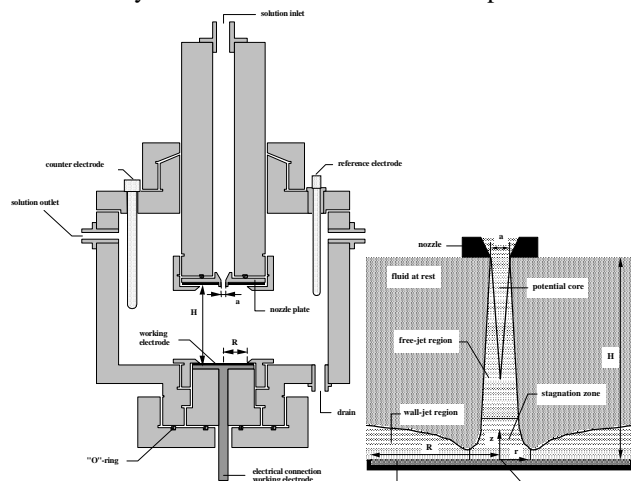


Figure1: Wall-jet cell and hydrodynamic flow pattern [1].

DC- and AC-anodizing are performed in 20 wt % sulfuric acid at different temperatures and current densities. For different jet flow conditions the local oxide thickness is measured with a calibrated EDX-method.

A clear influence of convection is observed on the anodic film thickness distribution, as demonstrated in Figure 2, and can be correlated with a non-uniform temperature distribution.

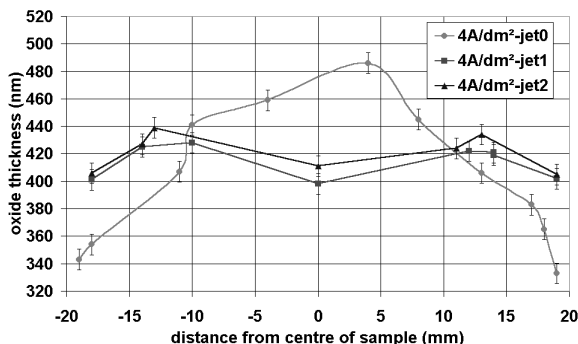


Figure 2: Film thickness distribution for DC-anodizing in 20 wt % H₂SO₄ at 25°C for 4 A/dm² and 20 s in a wall-jet electrode reactor for different jet flow conditions.

At higher local electrode temperature, the anodic film

grows thicker. The higher the local temperature, the stronger the field-assisted oxide dissolution, and hence -to restore anodizing equilibrium- the higher the local current density, leading to increased local film thickness [2].

For high current densities (>8A/dm² DC) local aberrant electrode phenomena are observed and accompanied by high local temperature peaks. While for DC-anodizing these phenomena, occurring during the initial period of anodizing and resulting in a singular thicker oxide spot on the electrode, are of temporary nature, for AC-anodizing at high current density, burning phenomena commence after a certain period of time and lead to fatal, mechanical film disruption.

An influence of convection is also observed on the boundary conditions between AC-anodizing and AC-cleaning; the latter being an aluminum etching process [3,4]. These observations have serious implications towards continuous high speed anodizing at high electrolyte temperature.

The electrochemical process modeling tool Miotras developed by ElSyCa has been used to determine the local heat transfer coefficients for different wall-jet flow rates on the electrode surface during steady-state anodizing, as shown in Figure 3. These simulations include the calculation of the electrolyte flow profile, the electrical potential, the current density and the temperature in the reactor and in the aluminum. The effects of convective heat transport and heat conduction in the electrolyte, heat conduction in the aluminum and the heat generated by the anodizing process on the current density distribution along the electrode surface, can be determined.

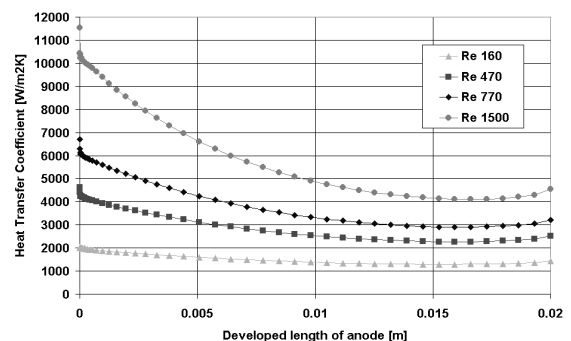


Figure 3: Local heat transfer coefficients for steady-state DC-anodizing in a wall-jet electrode reactor for different jet flow Reynolds numbers.

Acknowledgements

We acknowledge CORUS for their support; Flemish Institute for the Advancement of Scientific-Technological Industrial Research (IWT) for funding; Dr.G.Thompson (UMIST) for discussing wall-jet results; Dr.K.Shimizu (Keio Univ.) for TEM; M.Raes, M.Depauw, A. De Coninck and J.Van de Walle (VUB) for the experimental assistance.

References

1. Laevers P., Hubin A., Terryn H., Vereecken J., *J. of Appl. Electrochem.*, 3, 1023 (1995).
2. I.De Graeve, H.Terryn, G.Thompson, *J. of Appl. Electrochem.*, to be published.
3. I.De Graeve, H.Terryn, *Trans.IMF*, **78(1)**, 35 (2000).
4. I.De Graeve, J.Van de Walle, H.Terryn, *Trans.IMF*, **79(1)**, 22 (2001).